Drip Fertigation in Horticultural crops

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Application of Fertilizers to plantation, fruits and vegetable crops, though not uncommon, has not been considered adequately. Recently, Ghose (1999) based on recommended doses of fertilizer for different fruit crops projected the requirement of 826 thousand tons of N, 570 thousand tons of P205 and 115 thousand tons of K20 for the year 2000. Similarly, Singh and Kalloo (1999) projected 744 thousands tons N, 372 thousand tons of P205 and 272 thousand tons of K20 for vegetable crops. Thus, fruits and vegetable together have a potential requirement of 2.90 million tons of major nutrients.

Horticultural crops in national economy

Horticultural crops contribute to national income by sharing almost one fifth of the total income from agricultural produce. It is widely recommended that horticultural crops can play a vital role in competing problems of malnutrition, generating greater employment potential in rural areas and bringing nutritional security. A large variety of fruits, vegetables, flowers, plantation/spices crops, medicinal and aromatic plants, root and tuber crops cover roughly seven percent of the gross cropped area but contribute more than 18-20% gross value of agricultural output. As per the estimate available, the total area under these crops (excluding tea, coffee and rubber) was around 11 million hectares. As per FAO estimates, after China and Brazil, India ranks third largest producer of fruits (excluding melons) in the world, with 37.13 million tons of production (1997). The country contributes about 8.6% to the total world's fruit production. Mango, Banana, Citrus, Apple and Guava account for 80% of the total area and production of fruits. Again, after China, India is the largest producer of vegetables. India contributes about 9.2 % of the world vegetable (including melon) production. Presently, availability of vegetables in India is 130 grams per head per day in comparison to 280 gm recommended by the National Institute of Nutrition. The National Commission on Agriculture (NCA) had set a target of 45 million tons of fruits, 104 million tons of vegetables, 300 million tons of potato, 40 million tons of Cassava, 10 million tons of sweet potato, three million tons of onion, 20 billion coconuts, 60,000 tons of black pepper by 2000 AD (Paroda, 1995). During IX Plan annual growth rate of 7 per cent has been targeted for the fruits and vegetables against 3.05 per cent for food grain crops.

Fertilizer use and quality of horticultural crops

Fertilizers also influence quality of horticultural crops, particularly colour, shape, size, taste, shelf life and processing characteristics. Fertilizers also influence the physiology of plant and thereby determine the composition of fruits and vegetable produce and the resistance of these plants to environmental stress.

Soil and plant analysis

Fruit crops because of their deep root remification can take nutrients from deeper soil layers. Therefore, the general soil testing programme in which fertility status of 15 cm soil layer is assessed is not useful for fruit crops. Soil sampling from different layers up to 1.5 m will provide a better assessment of soil fertility status for fruit crops. Nutrient status of plant leaf is a better indicator of proper plant nutrition. Sampling of the particular plant portion provides better diagnosis of nutrient deficiency in the fruit crops. The plant part to be sampled and other conditions related to their sampling is presented in Table 1.

Table 1. Suggested Guidelines for Leaf/Petiole Sampling

Crop	Plant part to be sampled	Age, stage, position & other conditions
Apple	Recently matured leaf including petiole	June 15 to August 15 from Prunear base of current season growth at bloom stage.
Banana	20cm2 section of leaf 3rd fully open leaf blade on both side of midrib in centre of the leaf.	3rd fully open leaf
Grape	Petiole	45 days after pruning at bloom stage opposite to flower cluster.
Guava	Recently matured leaf	3rd pair in August or December at bloom stage.
Citrus	Leaves including petiole	Selection 5-7 month old terminal, spring cycle leaves of mature trees.
Ber	Recently matured leaf	Middle of the shoot 7-8th from apex. Keep central part of the leaf middle of the shoot at bloom stage.
Mango	Leaves including petiole	Collect 4-7 month old leaves from middle of the shoot.
Pineapple	Middle one third portion of white basal portion of leaf	Fully developed leaf 'D' leaf 3-4 months after planting.

Fertigation in horticultural crops

Improvements in fertilizer delivery techniques are sought for two reasons:

(i) Application of fertilizer in small doses spread across the entire growing season in an effort to match the crop nutrient requirements, to improve nutrient uptake efficiency, minimize losses, thus to maximize the returns per unit amount of fertilizer;

Table 2. Nutrient Removal by some Fruits and Vegetable Crops (Kg/ha).

Crop	Yield (t/ha)	N	P205	K20
Apple	25	100	45	180
Banana	40	250	60	1000
Citrus	30	100	60	350
Grape	20	170	60	220
Mango	15	100	25	110
Papaya	50	90	25	130
Pineapple	50	185	55	350
Cabbage	70	370	85	480
Carrot	30	125	55	200
Cauliflower	50	250	100	350
Cucumber	40	70	50	120
Egg Plant	60	175	40	300
Okra(bhindi)	20	60	25	90
Onion & Garlic	35	120	50	160
Spinach	25	120	45	200
Tomato	50	140	65	190

(ii) minimize nutrient leaching below the root zone, particularly of nitrate form of nitrogen, which can have negative impact on raising its concentration in the groundwater above the maximum contaminant limit that is recommended for drinking water quality.

In the case of large spacing planted tree crops, drip or under-the-tree micro sprinklers (micro irrigation) provide an opportunity to irrigate a certain portion of the total planted area, thus contribute to increased water uptake efficiency.

Application of fertilizers through irrigation system is referred to an 'fertigation'. Fertigation through microirrigation system provides a technique of application of water and nutrients to an area of the soil where most of the roots are present to coincide with the timing of nutrient requirement by the trees. Therefore, fertigation is expected to increase the nutrient uptake efficiency, thereby minimizing leaching losses compared with the application of fertilizer in dry granular form broadcast over a large soil area at less frequent intervals. In addition to the tree response, fruit yield and quality, the changes in groundwater nitrate concentrations impacted by the different fertilizer delivery methods.

The advantages of localized soil fertigation include: combined application of water, fertilizers and pesticides with high precision and uniformity; improved distribution and control of water and nutrients in the soil; and the potential for application of water and nutrients in accordance with the demands of the plant.

Fertilizer use efficiency

Nutrient	Fertilizer use efficiency (%)		
	Soil application	Drip	Fertigation*
N	30-50	65	95
P	20	30	45
K	50	60	80
* 95 % applied fertilizers taken by plants			

Water saving, Yield under fertiugation

Crop	Water saving (%)	Yield (t/ha)		
		Conventional Method	Drip	Fertigation
Banana	35	26	30	37
Sugarcane	29	120	160	207
Tomato	32	45	56	65

Fertilizers for fertigation

Speciality Water Soluble Fertilizers

Poly feed (19-19-19)
MAP (12-61-0)
Multi –K (13-0-46)
MKP (0-52-34)
SOP (0-0-50)

Normal Fertilizers

Urea (46-0-0)
Potash (0-0-60)

Methodology

The methodology adopted in the estimation of different parameters, including amount of fertilizers, frequency of fertigation, capacity of fertilizer tank, water requirement, capacity of drip system, injection rate and injection duration, has been discussed here.

Amount of Fertilizer Required

The amount of nutrients to be applied during any given fertigation and the total amount to be applied during the crop season depend on the frequency of fertigation, soil type, nutrient requirements of the crop and its availability in the soil5. The nutrients applied to soil by the fertilizers are not fully available to the plant due to leaching, run-off, volatilization and adsorption losses. Therefore, a correction factor suggested by Tisdale6 was used to compensate for these losses. Required amount of fertilizers was estimated as follows.

$$Fn = R \times Fcf \qquad (1)$$

Devices for fertigation

Fertigation Tank **Fertilizer injector**

where, Fn is the nutrient requirement, kg/ha; R, recommended dose of fertilizer for the crop, kg/ha; and Fcf is the fertilization correction factor. If nutrient content of a given fertilizer is n%, then the actual amount of fertilizer (RF, kg/ha) required to meet the nutrient requirement was estimated as follows.

$$RF = b\ Fn \times 100g/n \qquad (2)$$

Frequency of Fertigation

Fertilizers can be injected into the irrigation system at various frequencies such as once a day, on alternate days or even once a week. The frequency depends on irrigation scheduling, soil type, nutrients requirement of crop and the farmer.s preference7. In any case, it is extremely important that the nutrients applied in any irrigation are not subject to leaching either during that irrigation or during subsequent irrigations.

Capacity of Fertilizer Tank

The stock solution is prepared by dissolving the granular fertilizer in water. The amount of water needed to dissolve the required amount of granular fertilizer depends on its solubility. Depending upon the compatibility of the granular fertilizers, either one stock solution of N-P-K fertilizers or different stock solutions of N, P and K fertilizers were prepared separately. Stock solutions could be prepared for each fertigation or for injection during fertigations over a period of time8. The capacity of fertilizer tank was calculated on the basis of frequency of fertigation, area irrigated in one application, application rate and concentration of stock solutions prepared for fertigation.

$$Vt = RF\ b \times Ag/bC \times nfg \quad (3)$$

where Vt is the capacity of fertilizer tank, l; C, concentration of the fertilizers in the stock solution, kg/l; nf , number of fertigations during the crop season and A is the irrigated area, ha.

Irrigation water requirement

Irrigation water requirement was estimated on the basis of monthly pan evaporation data and crop coefficient as follows.

$$V = Ep \times Kp \times Kc \times Cc \times A \times 10 \quad (4)$$

where V is the total irrigation water requirement, l; Vd = (V/N), average daily water requirement, l/day; Kc , crop coefficient; Cc , canopy factor, (Cc = wetted area per plant area = 1.0 for field crops); Kp , pan coefficient (generally it is 0.8); Ep , total pan evaporation during the crop period, mm; and N is the crop duration, days.

Capacity of drip system

Capacity of drip system depends on the irrigation water requirement, daily operating hours, irrigation interval and water application efficiency. Drip irrigation system can be operated even for 24 h but only the required quantity of water is to be given. For the purpose, appropriate dripper capacity should be selected based on the infiltration rate of the soil and the water demand of the crop9. It is advisable to irrigate through drip irrigation daily to avoid moisture stress to plants. Capacity of drip system was estimated using the following relationship.

$$Q = Vd \times T/(b\ \eta a \times tg) \quad (5)$$

where Q is the capacity of drip system, l/h; T, irrigation interval, days; □a , water application efficiency (in fraction); and t is the duration of each irrigation, h.

Injection duration and rate of fertilizer solution

The fertilizer injection duration depends on the type of soil, nutrient and water requirements of the crop. A maximum injection duration of 45 min to 60 min is generally recommended10 with enough time for flushing of fertilizer residues from the drip lines before shutting the pump off. Injection rate refers to the volume of fertilizer solution injected during a specific period of time. To inject the fertilizer solution at pre-determined injection rate, the selected fertilizer applicator should be calibrated before starting the fertigation. After calibration, the duration of injection for different fertilizers may change as it depends on the concentration of the fertilizers in the stock solution and the desired quantity of nutrients to be applied during any fertigation. The discharge through the applicator depends on the duration of irrigation as well as on fertigation. The following equation11 was used to determine the injection rate of fertilizer injector.

$$Qi = (RF \times A)/(nf \times C \times tf) \quad (6)$$

where Qi is the injection rate of fertilizer solution, l/h; tf , duration of each fertigation, h. If different stock solutions are prepared for supplying different nutrients, their respective injection rates may be determined separately. Selecting injection rate of any one nutrient, fertilizer injector is calibrated and then revised injection periods for different stock solutions are determined.

Concentration of nutrients in irrigation water

The actual concentration of nutrients needed in irrigation water depends on the fertilizing material and the crop requirement. The nutrient concentration in irrigation water was determined12 as follows.

$Cf=Fn \times 106\ Vd \times nf \times Rt\ e\ j/b\ g$ (7)

where Cf is the concentration of nutrients in the irrigation water, ppm; and Rt , is the ratio between fertilization time and irrigation time (tf /t).

Computer Program: FERGON

A computer program FERGON in C++ was developed for determining different fertigation parameters based on the crop, climate, soil and fertilizers data. FERGON was developed on an algorithm based on the procedure discussed earlier.

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